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SIX SIGMA IMPLEMENTATION PRACTICES IN INDIAN FOUNDRIES AND BENEFITS DERIVED: CRITICAL EXAMINATION

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ABSTRACT

This paper describes benefits derived by application of Six Sigma in Indian Foundries. In the today's 21st Century and in era of globalization, producing world class quality castings as per the international standards needs multidirectional competitiveness. Indian foundry industries are continuously tried to gain a competitive edge in cut throat competition environment. So for sustainable growth and operational excellence in current market condition, Indian foundries are needed to produce the products which provide high quality at the lowest possible cost. Six Sigma has been widely used project-driven management approach to produce high-quality products with the lowest possible cost Six Sigma is the methodology having statistical base focusing on removing causes of variations or defects in the product or core business processes. This quantitative approach aims at improving efficiency and effectiveness of the organization. The Indian foundry industry is the fourth largest in the world. There are more than 7,000 foundries in India and most foundries (nearly 95%) fall under small and medium scale category It seems newer quality approach like 'Six Sigma' is not fully explored among Indian industries.

This paper discusses about tools and techniques of Six Sigma applied by different foundry, in order to achieve business excellence.

KEYWORDS: Six Sigma**,** DMAIC Methodology, Foundries, Benefits

INTRODUCTION

Six Sigma Concepts

Six Sigma has developed as one of the most effective business improvement strategies over the years. This quantitative approach aims at improving efficiency and effectiveness of the organization. It is the methodology having statistical base focusing on removing causes of variations or defects in the product or core business processes. The improvement focus is on business outputs which are of critical importance to the customers. In the current dynamic industrial scenario, quality alone is not the winning criteria; consistent supply of quality goods as per the committed delivery schedules makes the customers happy. Six Sigma `methodologies addresses the major root causes and guarantees the targeted results, both in terms of improvements desired and time span fixed. It is a disciplined, data-driven approach and methodology for eliminating defects in any process – from manufacturing to transactional, from products to services. This breakthrough improvement strategy delivers results of productivity, profitability and quality improvements based on its highly effective approach (Desai, 2008).

Sigma, (σ) is the Greek symbol for the statistical measurement of dispersion called standard deviation. It is the best measurement of process variability, because the smaller the deviation values, the less variability in the process. According to Six-Sigma philosophy, processes rarely stay centered – the center tends to shift above and below the target, by a value of 1.5 sigma. 3.4 defects per million opportunities (DPMO) for Six Sigma process is obtained by assuming that the specification limits are six standard deviations away from the process target value and that the process may shift nearly 1.5 sigma. The 3.4 DPMO value is the area under the normal curve beyond 6 – 1.5 = 4.5 sigma (Snee, 2000).

Six Sigma was a way for Motorola to express its quality goal of 3.4 DPMO where a defect opportunity is a process failure that is critical to the customer). Motorola set this goal so that process variability is ±6 S.D. from the mean. They further assumed that the process was subject to disturbances that could cause the process mean to shift by as much as 1.5 S.D. off the target. Factoring a shift of 1.5 S.D. in the process mean then results in a 3.4 DPMO. This goal was far beyond normal quality levels and required very aggressive improvement efforts. For example, 3 sigma results in a 66,810 DPMO or 93.3% process yield, while Six Sigma is only 3.4 DPMO and 99.99966% process yield (Masoud Hekmatpanah et.al. 2008).

Six Sigma Histories

The roots of Six Sigma as a measurement standard can be traced back to Carl Friedrich Gauss (1777-1855) who introduced the concept of the normal curve. Six Sigma as a measurement standard in product variation can be traced back to the 1920's when Walter Shewhart showed that three sigma from the mean is the point where a process requires correction. Many measurement standards (Cpk, Zero Defects, etc.) later came on the scene but credit for coining the term "Six Sigma" goes to a Motorola engineer named Bill Smith. (Incidentally, "Six Sigma" is a federally registered trademark of Motorola).

Bill Smith, a Motorola engineer, developed the Six Sigma programme in 1986 as a response to the necessity for improving quality and reducing defects in their products. The CEO, Bob Galvin, was impressed by the early successes, and under his leadership, Motorola began to apply Six Sigma across the organization, focusing on manufacturing processes and systems. Motorola established Six Sigma as both an objective for the corporation and as a focal point for process and product quality improvement efforts. The Six Sigma concept was tremendously successful at Motorola. It has been estimated that they reduced defects on semiconductor devices by 94% between 1987 and 1993(Douglas C. Montgomery and William H.Woodall 2008).

In 1991 also, Allied Signal, (which merged with Honeywell in 1999), adopted the Six Sigma methods, and claimed significant improvements and cost savings within six months. It seems that Allied Signal's new CEO Lawrence Bossidy learned of Motorola's work with Six Sigma and so approached Motorola's CEO Bob Galvin to learn how it could be used in Allied Signal.

In 1995, General Electric's CEO Jack Welch (Welch knew Bossidy since Bossidy once worked for Welch at GE, and Welch was impressed by Bossidy's achievements using Six Sigma) decided to implement Six Sigma in GE, and by 1998 GE claimed that Six Sigma had generated over three-quarters of a billion dollars of cost savings. (Source: George Eckes' book, The Six Sigma Revolution.)

By the mid-1990's Six Sigma had developed into a transferable 'branded' corporate management initiative and methodology, notably in General Electric and other large manufacturing corporations, but also in organizations outside the manufacturing sector.

By the year 2000, Six Sigma was effectively established as an industry in its own right, involving the training, consultancy and implementation of Six Sigma methodology in all sorts Six Sigma quickly very popular methodology used by many corporations for quality and process improvement,.(source www. business ball.com)

Over time Six Sigma has undergone many changes and from implementation in only manufacturing industries today the advantage of Six Sigma is being taken by service industries also. Successful implementation and growing organizational interest to six sigma method have been exploding in the last few years. It is rapidly becoming a major driving force for many technologies driven, project driven organizations (Desai, D. A. 2008)

Motorola, Honeywell and General Electric has gained profit from Six Sigma adoption and implementation, made other big organizations of the world to adopt methodology in 1990s to take beneficial results.(Snee, R.D. 2000).

Several major organizations. Motorola, GE, Allied Signal [now Honeywell], Ford, Johnson Controls, TRW, Delphi, Raytheon, Lockheed-Martin, Texas Instruments, Sony, Bombardier, Polaroid, 3M, and American Express are some of the organizations that have implemented Six Sigma (Hahn et al., 1999; Harry, 1998; Lanyon, 2003; Miller, 2001; Snee, 1999; Williams, 2003).

Definitions of Six Sigma

Six Sigma has been defined by many experts by numerous ways. In couple of initial definitions Tomkins (1997) defined Six Sigma as a program aimed at the near elimination of defects from every products, process, and transactions. Technically, sigma(s) is a statistical measure of the quality consistency for a particular process/product. The technical concept of Six Sigma is to measure current performance and to determine how many sigma exist that can be measured from the current average until customer dissatisfaction occur. When customer dissatisfaction occurs, a defect results (Eckes 2001).

It is a disciplined, systematic and data-driven approach to process improvement that targets the near-elimination of defects from every product, process and transaction (Firka, 2010; Montgomery, 2010)

Harry (1998) defined Six Sigma as a strategic initiative to boost profitability, increase market share and improve customer satisfaction through statistical tools that can lead to breakthrough quantum gains in quality.

The application of Six Sigma is growing and moving from the manufacturing field to encompass all business operations, such as services, transactions, administration, Research& Development (R&D), sales and marketing and especially to those areas that directly affect the customer (Hahn *et al.*, 2000)

As per Park (2002) Six Sigma implies three things: statistical measurement, management strategy, and quality culture. It tells us how good products, services, and processes really are, through statistical measuring of quality level.

Six Sigma is new, emerging, approach to quality assurance and quality management with emphasis on continuous quality improvements. The main goal of this approach is reaching level of quality and reliability that will satisfy and even exceed demands and expectations of today's demanding customer (Pyzdek 1999).

As a project-driven management approach, the range of Six Sigma applications is also growing from reduction of defects in an organization's processes, products and services to become a business strategy that focuses on improving understanding of customer requirements, business productivity and financial performance (Kwak and Anbari, 2006; Heavey and Murphy, 2012)

Six sigma is a formal methodology for measuring, analyzing, improving, and then controlling or "locking-in" processes. This statistical approach reduces the occurrence of defects from a three sigma level or 66,800 defects per million opportunities (DPMO) to a six sigma level of less than 4.0 DPMO (Bolze, 1998).

Linderman, Schroeder, Zaheer and Choo (2003) in defining Six Sigma stress up on process improvement and new product development by stating that Six Sigma is an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates.

Six Sigma has been adopted by many leading companies. The benefits are well documented for manufacturing industries and increasingly, in service industries (Wright &Basu, 2008).

Six Sigma is a synergistic mixture of many statistical and non-statistical tools and techniques which employs quality and performance improvement of the processes and products (Chhabilendra & Roul 2001), Six Sigma is a proactive and quantitative continuous improvement approach which improves bottom line of the organizations through reduction of costs, waste and non-conformance.

Six Sigma is a highly structured program developed by Motorola and used to improve quality world widely (Singh and Khanduja, 2010} Indian foundry industries an overview.

The Indian foundry industry is the fourth largest in the world. There are more than 7,000 foundries in India These units produce a wide range of castings that include automobile parts, agricultural implements, machine tools, diesel engine components, manhole covers, sewing machine stands, pump-sets, decorative gates and valves. 32.4% of total production of Indian foundries supplies goes to serve only automobile sector, which is quite substantial as compare to other sectors (Chaudhery, 2010) these units are mostly located in clusters with numbers varying from less than 100 to around 400 per cluster. Some of the notable clusters in this regard are Agra, Howrah, Batala, Coimbatore, Kolhapur, Rajkot and Belgaum (Chhabilendra and Roul, 2001).

In India, manufacturing industries like foundries do not enjoy monopoly but they have to face competition (Chaganti and Greene, 2002 & Bikram Jit Singh and Dinesh Khanduja) Sand Casting is the most widely used process to produce castings among the all casting processes. Especially, intricate shapes in large numbers can be easily produced through sand casting process. Several types of defects could occur during casting and considerably reduce the total output of castings, besides increasing the cost of their production. Whenever a defect occurs in castings, the various departments in the foundry normally blame each other for its occurrence. Defects may occur due to single cause or a combination of causes. Correct identification and finding the root causes for the defect is difficult due to the Involvement of various technical factors like Process Design, Process Flow, Pattern Shop, Sand Preparation, Core Making and Melting (Sahoo et al., 2008).

Foundries in India manufactures Gate Valves, Flywheel Outer Casings, , Flywheels etc., by using sand casting techniques. Earlier there was no strategy to control production defects and therefore, defects occurred per production were stochastic. Mainly defects occur due to Poor design, Lack of Knowledge in the usage of resources, Ignorance of Operational Instructions, Poor Material Handling, and Improper Planning of Managing Activities, Lack of Training and especially Poor Employee Commitment towards Work. The Employees' Attitude towards Quality Improvement was questionable. It was this work environment that was taken for analyzing and Six Sigma Program was tried by the research team to improve the process. (A. Kumaravadivel, U. Natarajan 2011).

Metal casting process is a complex process with several sub-processes, such as patternmaking, mold and core making, melting and pouring, heat treatment and cleaning and finishing. Six Sigma methodologies have been attempted in steel foundries to minimize the casting defects and improve profitability. Six Sigma uses DMAIC methodology to improve the processes. Six sigma heavily focuses on statistical analysis as it is data driven and is a methodical approach that drives the process improvements through statistical measurements and analyses. In view of the large number of factors that are responsible for the casting defects, the general statistical approach is not always the best (Dr.Hathibelagal Roshan)

Foundries, and indirectly, their customers, continue to pay a heavy price for poor quality. The immediate fallouts include loss of productivity (saleable castings per poured metal), and the cost of cutting and re-melting of rejected castings. Defective castings supplied to the customer lead to wasted machining cost, and may have to be recalled (which involves avoidable transportation cost), or repaired (high labor cost). On the other hand, six-sigma quality is regularly being aimed and nearly attained in many sectors of manufacturing, including semi-conductors, forging, plastic injection molding, and sheet metal stampings. Defect levels of 100 parts per million (ppm), that is, 0.1% rejections are within reach in pressure die-cast parts during regular Production (Ravi et al.2008& Desai et al 2012).

It is evident from the literature published so far that small and medium enterprises of Indian industries needs immediate introduction of Six Sigma methodology. Foundry industries, to become globally competitive, are not an exception. The process improvement methodology, that is, DMAIC can be applied to foundry processes to improve quality of the castings and thus reduce cost which can have ultimate impact on the bottom-line results. (Desai et al 2012)

With the reduction of geographical barriers and the pressure of competing in the global market, overall operational and service excellence has become a necessity for the Indian industries to remain globally competitive. Although many Indian industries have successfully embraced the Six Sigma business improvement strategy, the adoption of Six Sigma in Indian industries is not as encouraging as it should be. Approximately30% of Indian industries have applied Six Sigma in its business and the remaining 70% companies are not yet engaged with a Six Sigma initiative for a number of reasons. (Antony and Banuelas, 2002 & Bikram Jit Singh and Dinesh Khanduja 2012)

RESEARCH METHODOLOGY

The main purpose of this study is to explore the benefits which Six Sigma provides to the Indian foundries for improvement of their processes quality and compete with today's globally competitive environment in 21st century. This is an attempt to show directions to Indian foundries for implementation of Six Sigma projects. The strategy & methodology used is to collect the different literature (research papers) and case studies where Six Sigma approach was successfully implemented in Indian foundries. All the case studies which are selected in this paper are from established publications to show the real research and give directions and role model for Indian foundries... Most of the case studies are from Indian

foundries so problems & hurdles of different environment in different countries will not be evident. These case studies are taken from the established journals and publications. However most of the research studies are not disclosed easily by the authors, we have taken 25 case studies from Indian foundries to discuss the concept. The time period of various case studies are from 2007 to 2014. These all case studies are then compared from different perspective and presented into following sequence:

- Overview of case studies and publications
- Methodology adopted by case industries
- Tools and Techniques used.
- Benefits gained by foundry industries

GENERAL OVERVIEW OF CASE INDUSTRIES (FOUNDRIES)

The table 1 below gives referred no of these papers, the publication name (i.e. research paper title), the product of the case industry OF FOUNDRY INDUSTRIES. The referred name on the left most column indicates the name by which the publication has been referred in the rest of the review paper. The table 1 also gives information about the journal, authors' name and year of publication of the selected cases.

Table 1: General Overview of Case Industries (Foundries)

Referred No.	Title	Journal year	Author/Authors	CASESTUDY/product
I-1	Application of Six Sigma Methodology in a small-scale foundry industry.	International JournalofLeanSixSigma2014	E.V.Gijo, N. A.Jnanesh	Leaf spring Manufacturing in Foundry shop.
I-2	Empirical study on employee job satisfaction upon implementing six sigma DMAIC methodologies in Indian foundry–A case study.	International Journal of Engineering, Science and Technology 2011.	A.Kumaravadivel, U. Natarajan	The Company manufactures Gate Valves, Flywheel Outer Casings, and Flywheels etc., by using Sand Casting Techniques.
I-3	Cost Analysis of foundry Industry In Form of *Misrun* By Using Six Sigma.	International Journal of Research in Engineering& Applied Sciences Volume 4,Issue2(February2014**)**	Bhupinder VikasKumar Pradeep Kumar	The industry is making cast iron castings of submersible pumps components such as Upper housing, Motor Pulley, Mini Chaff cutter wheel in large scale.
I-4	Leveraging Six Sigma Disciplines to Reduce Scrap in Indian Foundry SMEs.	Small Enterprise Association of Australia and New Zealand 2013	Bigram Jet Singhand Dinesh Khanduja	A case study has been carried out in anon-ferrous foundry at Federal Mogul India Limited Bhadurgarh, Patiala(Punjab)It is a medium scale unit Used to cast pistons for export to US and use s mostly semi-automatic die casting machines
I-5	Casting effect Reduction UsingShainin Tool In CI Foundry–A Case Study.	Proceedings of I RF International Conference,04May-2014,	R.B.heddure, M.T. Telsang	A Case Study for Casting In Foundry Industries.

I-6	Increasing Bottom-Line Through Six Sigma Quality Improvement Drive: Case of Small Scale Foundry Industry.	Udyog pragati–The Journal for Practicing Managers Vol.36, No.2, April-June, 2012.	Darshak A.Desai	A Case Study for casting unit falling under small and medium scale enterprises (SMEs) category. The foundry is fully geared to meet the entire Range of requirements of casting of various industries like Cement, Mining, and Engineering industries in India.
I-7	Developing operation Measurement strategy during ix Sigma implementation: a foundry case study.	Int.J. Advanced Operations Management,Vol.4,No.4, 2012.Inderscience Enterprises Ltd.	BikramJit Singh, Dinesh Khanduja	A foundry case study, case study in a medium scale on-ferrous foundry has been conducted.
I-8	Capability enhancement of a metal casting process in a small steel foundry through Six Sigma: a case study.	Int.J. Six Sigma and Competitive Advantages, Vol.33, No.1, 2007.	B.N.Sarkar	In this case study Six Sigma methodology for overall improvement of performance of the furnace and the steel foundry was taken up.
I-9	Determination And Correction of Sand Casting Defect: By Implementation of DMAIC Tool of Six Sigma.	International Journal of Research in Engineering & ppliedSciencesVolume4,Issue1(January2014)	Bhupinder Singh	The study was done at Haryana (India)on Application of Six Sigma methodology. The industry was making cast iron castings of submersible pumps components such as Upper housing, Motor Pulley, Mini Chaff cutter in large wheel scal*e*.
I-10	Improvement of Sigma level of a foundry :a case study	The TQM Journal Vol.25 No.1,2013pp.29-43 Emerald Group Publishing Limited 1754-2731.	Sushilumar, P.S. Satsangi and D.R. Prajapati	The case study was based upon a leading automobile foundry industry located in north India. It was a grey automotive captive foundry, producing Grade-25 casting for well-known tractors.
I-11	Confluence of Six Sigma, Simulation and environmental quality An application in foundry industries.	Management of Environmental Quality: An international journal Vol.17No.2,2006 pp.170-183emerald Group Publishing Limited1477-7835.	H.Sekhar, R.Mahanti	Case study in foundry industry The foundry Under evaluation was equipped with wet scrubber(venture)for pollution control.
I-12	Does analysis matter in Six Sigma?:a case study.	Int. J. Data Analysis Techniques and Strategies, Vol.3,No.3, 2011.(Inder science Enterprises Ltd.)	Bikram Jit Singh and Dinesh Khanduja	A case study was conducted at Non Ferrous foundry at Federal Mogual India ltd at Bahdurgarh Medium scale unit Producing piston.

I-13	DMAICT:(a road map to quick changeovers.	Int. J.SixSigma and Competitive advantage, Vol.6,Nos.1/2, 2010. (Inderscience Enterprises Ltd.)	Bikram Jit Singh and Dinesh Khanduja	A case study carried out in light alloy foundry on how DMAICT approach of Six Sigma.
I-14	Essentials of D-phase to secure the competitive advantage through Six Sigma.	Int.J.Business Excellence, Vol.5,Nos.1/2,2012. (Inderscience Enterprises Ltd.)	Bikram Jit Singh and Dinesh Khanduja	A case study in a medium scale non-ferrous foundry has been conducted which has witnessed the effectiveness of suggested concept.
I-15	Six Sigma an Excellent Tool for Process Improvement – A Case Study.	International Journal of Scientific &Engineering ResearchVolume2,Issue 9,September-2011	Sushil Kumar P.S. Satsangi and D.R. Prajapati	The case study is based upon a leading automobile foundry industry, located in north India. It is grey automotive captive foundry, producinggrade-25 casting for well-known tractors company.
I-16	Scope of Six Sigma in Indian foundry operations: a case study.	International J.Services and Operations Management, Vol.13, N 2012.	Bikram Jit Singhand Dinesh Khanduja	Case study in Indian foundry SMEs.
I-17	Enigma of 'Six Sigma' for Foundry SMEs in India :a case study.	Int.J. Engineering Management and Economics,Vol.2,No.1201 1.	Bikram Jit Singh, Dinesh Khanduja	An empirical investigation has been carried out in a make-to-order type(medium-sized) foundry ,in which a modified Six Sigma approach DMAIC(S)has been implemented successfully ,to decrease the scrap of piston castings.
I-18	Quality and productivity improvement through Six Sigma in foundry industry.	Int. J. Productivity And Quality Management,Vol. 9,No.2, 2012.Inderscience Enterprises Ltd.	Darshak A.Desai	Thispaperillustratesareall ifecasestudyofpracticing SixSigmaatasmall-scalefoundry industry
I-19	Improving foundry Control: an investigation of cluster analysis and path model.	Int. J Productivity and quality Management, Vol. 2,No.4,2007Inderscience Enterprises Ltd.	Vivek V.Khanzode And J.Maiti	In this study, an attempt was made to model and control the melting process of a grey iron foundry in western India using cluster analysis and path modeling.
I-20	Design for Six Sigma to optimize the process parameter s of a foundry.	Int.J. Productivity And Quality Management, Vol. ,No.3,2011Inderscience Enterprises Ltd.	Sushil Kumar, D.R. Prajapatian And P.S. Satsangi	A case study is carried out for a foundry.
I-21	Introduce quality processes	Int.J. Productivity And Quality Management,	BikramJitSingh and Dinesh	A comprehensive case study in a medium scale

	Through DOE:a case study in die casting foundry.	Vol. 8,No.4,2011Ltd.	Khanduja	piston foundry has been performed to validate the various quality perspectives of given optimization approach.
I-22	Ambience of Six Sigma in Indian Foundries an empirical investigation.	Int.J. Six sigma and Competitive Advantage, Vol.7,No. 1,2012	Bikram JitSingh and Dinesh Khanduja	Case study in a medium scale die-casting foundry.
I-23	Defect control analysis for Improving quality and productivity :an innovative Six Sigma case study.	Int.J. Quality AndInnovation,Vol.1, No.3, 2011.Inderscience Enterprises Ltd.	M. Shanmugaraja and M.Nataraj, N. Gunasekaran	The application of Six Sigma program with Taguchi technique has developed an innovative cost effective methodology for controlling defects in die casting process in less experimental time.
I-24	Application of Taguchi method to Optimize the characteristics of green sand in a foundry.	Int.J. Business Excellence, Vol.4,No.2, 2011Inderscience Enterprises Ltd.	E.V. Gijo Johny Johny Scaria	Case study in Greensand foundry.
I-25	Quality& productivity improvement using Six Sigma and Taguchi methods.	Int.J. Business Excellence, Vol.4,No.5, 2011.Inderscience Enterprises Ltd.	M. Shanmugaraja and M.Nataraj N. gunasekaran	The defects in aluminum die casting business.

METHODOLOGY ADOPTED & OBJECTIVES BY FOUNDRY INDUSTRIES

Shown in table -2 In implementation of Six Sigma concept that there are mainly two methodologies for the Six Sigma, but most of the Indian foundries are starting their projects of implementation of six sigma with DMAIC approach to improve performance of their existing processes of foundries rather than going for DFSS approach to design their new processes or different casting products. Following Table 4 showing the methodology and goal which have been adopted by different considered case industries. It is clear from the table 2 that all the case industries have initiated with DMAIC (Define–Measure– Analyze–-- Control) methodology. DMADV is applicable to new product or process which is to be designed and implemented in such a way that it provides Six Sigma performance. Main objective of different foundries are also shown below.

Table 2: Methodology Used and Main Objectives

Referred Name	Methodology used	Main objectives
I-1	Define-Measure- Analyze-Improve-Control (DMAIC) approach	Main objective of this paper was to illustrate how the Six Sigma methodology was applied to small-scale foundry industry to reduce the rejection sand rework in one of its processes.
I-2	DMAIC(Define, Measure, Analyze ,Improve, and Control)based	Main objective of this study was to focus on implementing Six Sigma approach in order to reduce the incidence of defects and increase the sigma level of the sand casting process.
I-3	DMAIC approach	In this case study the three important part of industry were chosen for complete analysis The improvement in these defects can be done by the application of DMAIC approach. The study was done at Haryana(India) on application of Six Sigma methodology and Selection of tools and techniques for problem solving, because of its high rejection rate.

I-4	DMAIC approach	The study focuses on scrap reduction in foundries and tries to find out the reasons of low productivity index among Indian subcontinent. It briefly discusses some facts and figures about foundry scenario in world and in the India.
I-5	Shainin tool,	The Authors main objective was to apply a systematic procedure to identify as well as to analysis of major casting defects. Defects are responsible for time waste, money and eventually they affect productivity adversely. The defects need to be diagnosed Correctly For appropriate remedial measures; otherwise new defect may get introduced. The proper classification and identification of particular defect is basic need to correct and control quality of casting.
I-6	DMAIC Methodology	Major objective was to illustrate real life case study of Small scale jobbing foundry industries in India. Main objective wis phase wise application of DMAIC,& ultimately shows how bottom line of the foundry can be increased by Implementing Six Sigma. The parameters with DMAIC technique.
I-7	DMAIC Analysis	In this study main objective to formulate prospects to understand there as one of failure of Six Sigma particularly in SMEs and it has been found that doing ‘wrong operation measurement’ is one of the major reasons in them. It enlisted the measurement phase in detail and proposed a more applicable methodology to execute operation measurements comprehensively, as far as their industrial applications are associated. It also acts as a road map for short t listing the relevant measurement tools.
I-8	DMAIC Analysis	In this case study, Overall equipment Effectiveness (OEE) fora0.5Toninductionfurnace, which is a metric for Total Productive Maintenance initiative, has been calculated. As this performance was below the expectation level and resulting in t o outsourcing of jobs at higher cost, the Six Sigma methodology for overall improvement to Performance of the furnace and the Steel foundry was taken up.
I-9	DMAIC Approach.	This case study deals with the reduction of rejection due to Casting defects in a foundry industry. The industry was making cast iron castings of submersible pumps component such as Upper housing, Motor Pulley, Mini chaff cutter wheel in large scale and having rejection in the form of slag inclusions The major objective was reduced this defects.
I-10	A DMAIC-based Methodology	The purpose of this paper was to explore Six Sigma practices in a casting industry, which could improve the green sand casting process in a foundry by reducing the casting defects. The goal was to determine which variables influenced this evolution and the relative weight of critical success s factors as the methodology developed.
I-11	SixSigma DMAIC Methodology	The aim of the research was to use an integrated approach– simulation and Six Sigma to improve the ambient air quality Simulation has been used to improve and control the environmental efficiency by monitoring the performance of the Venturi Scrubber the pollution control equipment, by running the model under varying conditions
I-12	DMAICstrategy	In this study various prospects have been Formulated to understand here as one of failure of Six Sigma particularly in SMEs and it has been found that doing ‘wrong analysis’ is one of the major reasons in them. It highlights the analysis phase and proposed more applicable forms for classification of analytical tools as far as their industrial applications are

		concerned.
I-13	DMAICT(DMAIC(Define–Measure– Analyze–Improve Control and Technology transfer) approach of Six Sigma	This paper deals with a study carried out in light alloy foundry on how DMAICT approach of Six Sigma concept has decreased the die changeover times effectively.
I-14	DMAIC Methodology	The case study takes in-depth look at the origins, advantages and disadvantages of Six Sigma and describe show it Relates to some of the other Quality initiatives in industry .DMAIC strategy of Six Sigma is briefly explained and realized The significance of define (D)-phase, specifically.
I-15	DMAIC Methodology	In this paper, the prime focus was on minimizing the defects, developed in the Cast-iron (grade-25)differential housing cover castings manufactured by the greens and casting process
I-16	DMAIC Methodology	This case study emphasizes on the immediate need of high operation performances in foundries by uncovering some feeble production metrics of Indian foundries. Where it discusses versatile challenges before foundries in India there it also highlights some advantages of Indian scenario as far as scope of productivity enhancement through Six Sigma is concerned
I-17	DMAICS	The main objective of this case study was to achieve customer satisfaction with continuous improvement in quality .An empirical investigation has been carried out in a make-to-order type (medium-sized) foundry, in which a modified Six Sigma approach DMAIC(S)has been implemented successfully, to decrease the scrap(or defects) of piston castings
I-18	DMAIC;	This paper explains phase wise application of define–measure–analyze–improve control methodology and ultimately shows how break through improvement can be brought in quality and productivity in a foundry industry.
I-19	Path Modeling	Main objective was cluster analysis and the raw material, Process and quality variables were grouped into four clusters. Then path modeling was conducted to model the inter relationships of the quality, process and raw material characteristics of each of the four clusters separately.
I-20	Taguchi method; Process Improvement	Six Sigma tools are applied for the defect reduction. It analyses various significant process parameters of the casting process of a foundry ,located in north India .In the first stage, a set of process parameters that contribute various casting defects are identified.
I21	DOE,ANOVA; Analysis of variance	This paper deals with various problems of industries which act as bottlenecks in the path of successful optimization of processes, specifically for foundry units and further it chalks out an integrated approach of design of Experiments(DOEs) for its implementation in product or process type industrial environments
I-22	DMAIC	The present Indian foundry scenario has been reviewed in terms of types of foundries ,their production trend and geographical clusterification A thorough literature survey has been performed to highlight the status of foundry industry at global level and position of India in context to other countries has been found.
I-23	DMAIC	This research study proposes an innovative analysis for controlling the defects in aluminum die casting industry. In this Analysis, casting process of a two-stroke engine oil pump body,was concentrated. The component selected has often rejected due to blowhole defects .Six Sigma, the zero defect

		approach, was used in this study. Define measure, analyze, improve and control (DMAIC) problem solving methodology is applied for problem analysis. Taguchi's experimental design was used for process validation and improvement.
I-24	Taguchi method	This case study addresses an approach based on Taguchi method for optimizing the ingredients of green sand in a foundry.
I-25	DMAIC	This research study proposes an innovative analysis for controlling the defects in aluminum die casting business. Six Sigma DMAIC (define measure, analyze, improve, control) methodology is used to analyze the problem. Process validation was done with Taguchi DOE and ANOVA analysis at95%confidenceshowedthat the metal temperature is the vital process parameter causing defects.

DIFFERENT TOOLS AND TECHNIQUES USED

According to ISO 13053-1 standard, there is an existence of so many tools and techniques which are normally used in different phases of DMAIC approach (Eckes G 2003). These tools and techniques can be management or statistical base. These all tools are not suitable for Indian foundries. Table 3 showing the various tools and techniques used by different case industries in Indian environment. General tools and technique which are used is shown in table 3.

BENEFITS GAINED BY CASE INDUSTRIES

The main aim of foundry industry is to earn profit and compete into today competitive global customer-oriented market. This can be achieved by improving the performance of the industries in terms of increase in quality and productivity. Quality and productivity can be improved by reduction in waste, rejection, rework, cycle time, idle time and scrap by effective application of Six Sigma. The foundry industries which we have taken for study have also gained so many benefits by reducing rejection, rework or cycle time. Various benefits gained by different foundries industries are shown in table 3.

Table 3: Tools & Techniques Used &Benefits Gained by Case Industries

Referred No.	Tools and Techniques Used	Benefits
I-1	ANOVA ,Taguchi method DOESIOPC R.&Rstudy Cause& Effect Diagram Process Capability Analysis S/N ratio Plot	A s a result of this study, the overall rejection was reduced from48.33to0.79percent, which was remarkable achievement for this small- scale industry .The finance department of the company estimated the annualized savings due to the reduction in rejection and was to the tune of USD8,000peryear.
I-2	Pareto, Ishikawa Diagram, Cause-and-Effect Matrix, FMEA Statistical Package for Social Sciences (SPSS–ALPHA SAV)for the standardized Cronbach's Alpha and the analysis.	In this case study, they have implemented DMAIC based Six Sigma approach to reduce the defects rejection percentage of a flywheel sand casting process. Implementing DMAIC (Define, Measure, Analysis, Improve, Control), Tangible results were achieved and rejection percentage decreased to 14.78% from 20.65 %, an equivalent improvement from 3.32 σ to 3.47σ The company's profit increased to Rs.4.88 from Rs.1.36 per component and earned more than Rs.17000 profits during the project period.
I-3	Pie chart, histograms	The rejection due to Blowholes defects were

		reduced from 6.74% to 2.01%. The rejection due to slag defects were reduced from 5.7% to2.41%.The rejections due to Misrun defects were reduced from 4.47 % to 1.57% by increasing temperature & improve the size of gates. The overall result of present work is clearly shows that by applying DMAIC rejection has reduced from 16.96% to 5.99 % and saving of cost Rs 53357 (four months) and monthly saving of cost Rs 13339.
I-4	Sources of Variations (SSVs), Analysis of Variance (ANOVA), Design of Experiments (DOE).QFD. Voice OF Customer, Sigma Calculator, Pareto Charts, Cause and Effect Matrix, Gauge R&R study, Bias Checking and Stability Test.Value Stream Mapping	Over all sigma level has been raised by 0.24 by reducing the scrap of a non- ferrous piston foundry from 22% to 10% after successfully implementing the DMAIC.
I-5	Shainin tool, Flow Diagram	By controlling the process parameter like O.D on the specified range, it gives minimum % rejection. So that range for O.D. of pourer in casting process has finalized 64.15 to 65.15.By controlling Carbon value is 3.38 to 3.52 has no Rejection in casting. This percentage kept between them by proper pouring of alloys percentage Shainin tool works on elimination level. This tool useful for quality improvement & by this tool eliminates the process. It can be achieve 95% confidence defect.
I-6	CTQ Tree,Paretochart, SQC. Various Charts	The no. Of rejection per year in cooler plate casting was reduced from 125 to70 with 44% financial saving. The No. of Rejection per year in Hammer casting was reduced from 175to 90 with 45%financial saving. The no. of rejection per year in Hammer casting was reduced from 155to 120with 22.5%financial saving.
I-7	Susceptible Sources of Variations; SSVs; SIPOC diagram; failure mode and effect analysis; FMEA; process capability; cause and effect matrix ;bias; stability; measurement system analysis ;MSA; Gauge repeatability and reproducibility; Gauge R&R.	Six sigma projects have imitated to reduce the scrap of export piston from 20% to 10%. The benefits of measure phase are to reduce time & efforts with the use of proper operation measurement tools.
I-8	CTQ; normality testing; OEE; process capability; TPM. Software packages like MINITAB and STATISTICA	When project was implemented in small scale foundry in oct-2003,both the arability and utilization of furnace increase which resulted in enhanced overall Equipment effectiveness(OEE) As well as monthly production of furnace was also increased for 70 to 88 percentages in six month. This reduces expenditure on outsourcing and annual saving of Rs. 3.7 million.
I-9	Pie chart ,histograms	From the result of the application of DMAIC approach in the foundry shop the following are results were obtained. The rejection due to slag defects were reduced from 5.77 % to 2.41% by using slag traps in gating system.. The overall result of present work clearly shows that by applying DMAIC approach the rejection has been reduced from 16.96% to 5.99 %

		and saving of cost .
I-10	Taguchi methods, DMAIC, Process, Improvement, Defects, Applications, Analysis, Analysis of variance, Parameters DOE, signal-to-noise (S/N) ratio CTQ Analysis. ANOVA.	Optimization of the process parameters of the green sand castings process, which contributes to minimize the casting defects. The optimized parameter levels for melt shop process are steel (48 kg), pig iron (195 kg), cast iron (350 kg),ferrochrome 1.2kg), ferromanganese (3.5 kg) and ferrosilicon (5 kg). The experiments also give a clear picture contribution to the variation in the quality of casting process without much investment.
I-11	Simulation .FMEA Cause And effect diagram.	The integrated application of Six Sigma and simulation has been successful in reducing particulate emissions from 200 milligram per cubic meter to less than 20 milligram per cubic meter and sulphur dioxide emissions from 45 milligram per cubic meter to less than 4.5 milligram per cubic meter thus reducing air pollution Thus proposed approach was reliable and the results obtained ware promising.
I-12	Susceptible Sources of variations; SIPOC diagram; quantitative analytical tools; one factor at a time; OFAT; one way ANOVA; t-test; regression analysis; fitted line plot; normal probability plot; industrial statistics.	Main Benefits of the Analysis phase was to reduce the unwanted SSVs, which is very vital for analysis phase. So Six sigma team can focus on way in improvement phase to reduce scrap. The systematic way and proper selection criteria of analytical tools also helps sigma team to priorities more serious CTQ factors & to decrease project repose time and effort. Other main Benefits of study in Foundry was to bring out importance of analysis phase in DMAIC, to reduce time and efforts.
I-13	Industrial engineering tools like 5-Spoke-yoke . value stream mapping; job matrix; re-scheduling; work sampling, value stream mapping and man-machine chart fish- bone analysis, rescheduling and externalization of setup activities Pareto chart	The overall equipment efficiency of heating oven had been increased by 34%, die casting was 22% and shot blasting machine was 11%. The reduction in change over time was nearly 66%. Increase in lime production was 66% Reduction in change over cost was also 66%. The DMAICT approach of six sigma restrict the setup son time of 5TS-HC die to almost 11 hour for 32 hours which in turns yields the annual saving of 49,40 000 INR.
I-14	D-phase; cost of poor quality matrix; Gantt charts; supplier-input-process-output- customer diagrams; SIPOC; Pareto analysis; project charter; casting defects;Cpk; critical to quality factors; CTQ	Benefits from the implementation on project can be calculated for the scarp, reworks and daily production reports. The cost of quality (COPQ) matrix has calculated the saving of around 30.7 lakh &scrap was reduced from 20% to10%.
I-15	Critical to Quality(CTQ), S/Nratio ANOVAFor CastingDefects	The optimized parameter levels for green sand casting process are moisture content (4.0%), green strength (1990 g/cm2), pouring temperature (14100C)and mold hardness number vertical & horizontal (72&85) respectively. The experiments also give a clear picture of each factor's contribution to the variation in the quality of casting process without much investment.
I-16	Critical to quality variables ;automotive mission plan; AMP; process mapping;	Six Sigma has been implemented to decrease the scrap (or defects) from a two wheeler's piston

	cost of poor quality; response surface methodology; RSM; contour plot; process audit sheet p-chart; Sigma-calculator; measurement system analysis; MSA; India.	castings by 15.02% appreciably. It is one of a rare but successful Six Sigma pilot study that uses response surface methodology as an optimization technique, among Indian die casting foundries.
I-17	Design of experiments; DOE; measurement system analysis; MSA; failure mode and effect analysis; FMEA; non- conforming products; cost of Poor quality; hypothesis testing; defects per million opportunities ;process capability; DMAICS; analysis of variance; ANOVA; India.	Design of Experiment (DOE) has optimized casting process parameters like cooling time metal temperature etc. In production run of 3 months at optimum value scrape was reduced to3.5 % from 7%.Financial benefits to company was 16.3 lakh per annum.
I-18	Six Sigma; DMAIC Define–measure– analyze–improve–control; SSI small-scale industry; foundry industries; Indian industries.	The sigma level of grey iron casting improved from 1.979 to 2.260 and that of SG Iron casting from 1.638 to 1.954. Increased sigma level of casting are more than 50 % so company could produce more casting with fewer rejection and rework. The net turnover of company would increase by 25% for the production of flange casting. Overall cycle time reduces to17.34 hr form 23.7 hr which increased by 27% .
I-19	Multivariate control scheme; setting process parameter	Main benefits of presence approach was to find out relationship among variables present in the melting process of grey cast iron to develop and easy &effective control scheme for the melting process in foundry. The present study can help in gaining useful insight for foundry supervisors and operator into the melting process.
I-20	An orthogonal array, the signal-to-noise ratio and analysis of variance criterion	Application of six sigma & Taguchi Experimental design for green sand casting improved quality & stability of casting process. By using Taguchi method casting defects are reduced from 5.185 % to 3.202%.
I-21	Full factorial design of experiment; blocking; ANOVA ;analysis of variance ;orthogonal array; OFAT; one-factor- at-a-time; response surface methodology	By successfully implementing DOE technique it was estimated hat approximate financial saving was 20.7 lakh, per annum. Scarp in cast iron piston was reduced from 21% to 10%.
I-22	DMAIC project; scrap; Rework; analysis of variance; design of Experiments and process audit sheets.	By optimizing input process factors (parameters in green) the output factor (response) has been coming out to be around 15% to17% and it was the aim of the study, which has been achieved successfully by implementing design of experiments technique. Financially, it was estimated that approximately saving of 46.2 lakhs per annum have been incurred by reducing the scrap of pistons from 31% to15% (approx.) and it is a substantial achievement for a medium scale non-ferrous foundry unit. Sigma level increased by 0.3 After improvement control measures have successfully run the piston foundry for consecutive two months at around 16.2 % scrap only and inculcates savings of around 3.8 lakhs, which is un-ignorable for a medium scale Indian foundry.
I-23	Six Sigma; define measure, analyze, improve and control; DMAIC ;Taguchi	In this study process yield could be attained at the combined Settings of parameters metal

	experimental design; analysis of variance; ANOVA; signal to noise ratio;S/N.Ratio	temperature at 715 degree centigrade, Intensifier pressure at 220 kg/cm2, degassing frequency of 320 shots/degas. Pooled ANOVA analysis has performed, and found metal temperature and degassing frequency are vital process parameters which contributed nearly 84% of variations in output casting quality. Casting process capability improved from 2.51 σ to 3.03 σ by reducing the defect rate by 12.42% (17.22–4.8).
I-24	Taguchi method; orthogonal array; noise factor; analysis of variance; ANOVA signal-to-noise ratio ;S/N ratio; permeability; greens and; Compression strength	As a result of the experimentation, in addition to the identification of optimum levels for the ingredients, the proportion of Mennonite and coal dust was reduced considerably. This was leading to a large financial benefit for the company.
I-25	DMAIC; Taguchi experimental design; ANOVA;signal to-noise ratio; S/N ratio.	The casting process was capability improved from 2.51s to 3.03s by reducing the defect rate by12.42% (17.22–4.8). The estimated savings generated from this project were at least INR 200 000. The results of this project provided greater stimulus for the wider applications of Six Sigma methodology across the company in the future. The efficacy of Taguchi DoE was realized by the management and the project team.

Lessons Learned

It is observed form various case study regarding the deployment of improvement initiatives and the associated Six Sigma methodology. The learning from this initiative are summarized for implementing future improvement activities effectively. Key lessons learned from the various case study focus around the leadership activities, involvement of people in improvement initiatives, data collection and subsequent data-based cause validation. Generally, critical success factors (CSFs) such as management commitment, leadership and training are very crucial for the success of the Six Sigma projects it was identified that improvement initiatives require strong leadership support not only at the higher level but also in the middle level of the organization. Most of the time, people at lower levels in small traditional organizations have a fear of job security. Quite often they think that if improvement projects are carried out, and cycle time and rework in the process are reduced, that may lead to reduction of head count and loss of job opportunity in the organization. Thus, giving awareness training in the Six Sigma methodology to the lower-level people in the organization about the focus of this improvement initiative will help them to understand

The purpose of this methodology and drive away any fear about the end result. This will create sense of urgency for improvement projects at lower levels of the organization .One of the reasons for success of this study was the strong support from the champion. The champion was keen to implement the Six Sigma methodology for addressing process problems in the organization. Especially during the DOE, champion’s strong support helped the team to draw meaningful conclusions. This shows that knowledge about the Six Sigma methodology is essential at every level of the organization for successful implementation. Organizational learning integrated with DMAIC methodology can provide a useful framework for successful Six Sigma implementation. This can be an aid in strengthening the “voice of the customer”, the measurement capabilities as well as the effectiveness and the efficiency of the processes (Lagrosenet al., 2011; AL-Najemet al., 2013). Training imparted during the measure phase on technical details of the process under study, data

collection plans and some of the key tools of the Six Sigma approach were the backbones in achieving the project goal. Involving the people from all levels in the organization in the development of the data collection process and sharing the inferences from data analysis with them greatly helped in getting support for collecting the data. Quite often the shop-floor workers are not aware of the technical details of the process they are working with. Proper training on the technical details will help them to do process-based thinking, recognize variation in the critical characteristics and focus on breakthrough improvement in performance. During the improvement phase, support from all levels of the organization is required for successful implementation of the solutions (E.V.Gijo et al 2013).

Six Sigma strategies in Indian foundry industry by reducing scrap/waste from the operations, thus greatly improving the production efficiency. ‘Project based’ approach for Six Sigma implementation is more motivating and helps a lot to demystify various fears on Six Sigma. A cadre with sound theoretical knowledge on different statistical tools and software needs to be built up in the management, so as to bridge the gap between the theory and practice of Six Sigma and appreciate its potential while bringing in business excellence Beside non-ferrous foundries, Six Sigma approach can be explored for ferrous foundries to bring breakthrough in rejections and increase yield per annum. It can also be used in energy intensive units, as it not only enhances productivity by process improvement but also it is a step to create ‘zero defect units’ which indirectly reap huge energy/power savings (Singh and Khanduja, 2012b).

The Global Market is becoming more Quality Conscious. To compete in such a competitive environment, companies need to adopt an efficient technique that can assess and take a diagnostic approach to meet customer needs and expectations. Nowadays, the industrial world has realized that the Six Sigma Philosophy is certainly a viable solution to their foundry problems. It is fact that the efficiency and performance level of the sand casting process can be improved by adopting a Six Sigma approach. Enhancing the Job Satisfaction upon Six Sigma Implementation was analyzed Awareness Training or Sensitivity Training also was arranged according to the nature of requirement of the Employees to convert them into Green Belt (GB), Black Belt (BB), and Master Black Belt (MBB) etc. The production processes of casting parameters should be deeply analyzed by tools like FMEA, Taguchi and Regressions to improve their process accuracies. Lastly, this procedure hasbeen shown to be an efficient and effective procedure for implementing and achieving six sigma. More research in this area is necessary to contribute to the science and practice of Implementation of Six Sigma or any other process improvement model, to reduce waste and create value.(A. Kumaravadivel1 et al 2011).

For effective implantations of six sigma project DMAIC has been considered as an approach to improve quality of product and process and reduction in rejection of industries. The DMAIC approach provides a suitable visible road map for entire work force to achieve new knowledge. Accuracy of this approach is very high.

Metal casting process is a complex process having sub-processes. Six Sigma methodologies are used to optimize the process and minimize casting defects. Sometimes the conventional statistical tools and techniques are available today are not enough to be effective in analyzing the casting defects and optimize the processes to minimize the impact on cost of quality. The reason for these include: the statistical techniques assume known distributions to the unknown foundry processes; the need for specially designed experiments; the need for carrying out a very large number of experiments in view of the large number of factors; the need to carryout specially designed experiments on a limited number of castings and the need to filter the potential factors into a manageable number of factors. Process optimization software based on pattern recognition is found to be suitable to optimize foundry processes and to minimize the casting defects. A six sigma methodology is presented to address the issue of casting defects in steel foundries with the exception that a pattern

recognition process optimization software is used instead of DOE techniques.(Dr.Hathibelagal Roshan).

Foundry process involves number of stages. At each stages no. of & different type of defect generated due to some operation related or due to incorrect process related. The defect need to be diagnosed correctly for appropriate remedial measures, otherwise new defect may get introduced. Six sigma it works on elimination process.

The implementation of Six Sigma programs to reduce variation or waste from the operations and would inspire Indian SMEs to takebenefit from this interesting methodology by inculcating 'project-based' approach for Six Sigma implementation rather than planning, training or investing here and there for accumulating various resources required for Six Sigma approach. The benefits incurred from success of different small or big DMAIC projects would motivate the employers to invest on these resources later on (Feld and Stone, 2002). This is more or less a practical approach to implement Six Sigma in Indian foundry scenario, which will also demystify various myths and phobias against Six Sigma. It is particularly relevant because today's competitive environment demands that companies reduce waste to meet or exceed efficiency and responsiveness requirements of customers. The pressure to pursue new ways of thinking as a source of competitive advantage is rising day by day (Vote and Huston, 2005). More research in this area is still necessary to contribute to the science and practice of implementation of Six Sigma or any other process improvement model to reduce waste and create value particularly in the foundries of developing nations like India.

CONCULSIONS

The main objective of this paper is to illustrate how the Six Sigma methodology was applied to various small scales, medium scale foundries to reduce rejection and reworks and defects and increase sigma level. Critical examination of implementation of six sigma covers all types of foundry like green sand casting foundry, die casting foundry, aluminum die casting foundry, grey iron foundry etc. in various sectors.

The other main objective is to examine various tools and techniques used and methodology applied to productivity & quality standard level in Indian foundries.

From study it is found that most of the Indian foundries are starting their projects of six sigma with DMAIC approach to improve performance of their existing processes of foundries. Major tools and techniques used in various papers are Statistical tools , Scatter diagram (correlation), Run charts, SPC control charts & SQC Charts, Process capability analysis, Measurement system analysis, Design of Experiments (DoE),Taguchi methods, ANOVA, Hypothesis testing, Regression analysis, Team problem solving tools, Process flowchart/mapping, Cause and effect analysis & Diagram, Affinity diagrams. Process analysis & Chart,5S Practice, Matrix analysis, Failure Mode and Effect Analysis(FMEA),.Kaizen ,SIPOC (Suppliers, Inputs, Process, Outputs, Customers),PDCA (Plan, Do, Check, Act),Poka-Yoke (Mistake proofing),Benchmarking, Quality costing analysis, Cost of Quality, Decision matrix, Regression/correlation analysis, Fishbone diagram etc. Various software like Minitab, are also used for analysis of results in various foundries.

From critical examination of various foundries the main benefits obtained in various foundries are reduction of scrap rate, cycle time, reduction of delivery time, reduction of waste, reduction of process variability and operational cost.

The other main benefits observed in this study are increase in profitability, productivity, six sigma level, and company image etc.

The third benefit of the study is improvement in employee's morale, improvement in attitude of employees

towards quality and problem solving, improvement in attitude of top management towards quality and problem solving and to increase profit.

So finally we can conclude that these paper shows Six Sigma strategy in Indian foundry industry by reducing defects, scrap, and waste from the operations in foundries, thus it effectively improve production efficiency, and productivity with improvement in six sigma quality level DMAIC based methodology is more motivating and helps to remove various barriers in implementation of six sigma. With the help of effective theoretical knowledge on different statistical tools and software &application of various tools in various DMAIC phases we can bridge the gap between theory and practice to needs to be built up in the management, so as to bridge the gap between the theory and practice of six sigma for increase profit margin and bring business excellence. Six Sigma approach can be applied for various Indian foundries to bring excellent results and less rejections and increase yield per annum. Six sigma can also be used in various foundries to enhance productivity by process improvement and to make 'zero defect units' which brings huge cost savings.

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